POWER SUPPLY DEVICE FOR A TIRE-PRESSURE SENSOR

Background Information

Tire-pressure sensors having batteries for power supply are known for motor vehicles. These sensors are located in the tire and include a sensor element whose output signal is encoded and transmitted by a transmitter to the receiver in the vehicle. One problem with these sensors is the power supply, usually a battery having a short lifetime. The toxic substances of which batteries are made are equally critical from the standpoint of possible disposal.

Summary Of The Invention

The present invention relates to a power supply device for a tire-pressure sensor, including a generator which is corotational with the tire (i.e., fixedly mounted on the wheel or tire or valve) in which an electric voltage is generated by electromagnetic induction. This has the following advantages:

- a long lifetime,
- continuous operation is possible due to temporary storage of the power generated,
- toxic substances are avoided by eliminating batteries,
- simple installation is possible by mounting the device on the valve, and
- small geometric dimensions of the system as a whole are possible by mounting, i.e., installing, the device on the valve.

An advantageous embodiment is characterized in that

- the generator contains a magnetic circuit and
- the induced voltage is generated by a geometric change in the magnetic circuit.

A voltage is therefore generatable in a simple and robust manner.

An advantageous embodiment is characterized in that the geometric change in the magnetic circuit is achieved by a change in the air gaps.

Another advantageous embodiment is characterized in that the magnetic circuit contains at least one permanent magnet. This makes it possible to generate a magnetic field easily and without expending energy.

An advantageous embodiment is characterized in that the magnetic circuit

- includes a stationary, magnetically conductive core, and
- includes a movable, magnetically conductive core, and
- the induced voltage is generated by a relative change in position of the movable core with respect to the stationary core.

This advantageously permits a simple geometric construction.

An advantageous embodiment is characterized in that the movable core moves along a guide.

Another advantageous embodiment is characterized in that a restoring spring is mounted on the movable core for returning the movable core to its starting position after a relative change in position.

Another advantageous embodiment is characterized in that the movable core is mounted on a plate spring which allows a one-dimensional change in position of the movable core, i.e., the movable core can move along a curved path.

Another advantageous embodiment is characterized in that the movable core is mounted on a torsion bar which allows a two-dimensional change in position of the movable core, i.e., the movable core can move over a two-dimensional surface.

In all these embodiments mentioned last, inexpensive production is possible due to the use of field-tested components.

Another advantageous embodiment is characterized in that the size of the relative change in position is limited by at least one stop.

An advantageous embodiment is characterized in that the stationary core contains a coil in which the induced voltage is generated. Since the coil is mounted on the stationary core, the coil feeder lines do not move while the generator is in operation.

Another advantageous embodiment is characterized in that the relative change in position is caused by an acceleration and/or a change in acceleration of the tire.

An advantageous embodiment is characterized in that an electric current is generated by the electric voltage, resulting in a charge buildup in an energy storage mechanism (capacitor, battery, ...).

Brief Description Of The Drawings

Figure 1 shows a block diagram of the design of the present invention.

Figure 2 shows a tire and the accelerations that occur.

Figure 3 shows a first embodiment of the generator.

Figure 4 shows a second embodiment of the generator.

Figure 5 shows a third embodiment of the generator.

Detailed Description

While driving, sizeable accelerations occur in the wheels of motor vehicles. This includes centrifugal acceleration, which may be very high (up to approximately 400g; g = gravitational acceleration), and other accelerations in the tangential direction as well as in the transverse direction of the vehicle. These accelerations are shown in Figure 2, which shows on the left a side view of a wheel having a tire (rolling past the observer) and on the right a front view of a wheel having a tire (rolling toward the observer), where

200 = tire,

201 = rim,

202 = valve,
203 = seal, and
204 = tire-pressure sensor.

In addition, Figure 2 shows a tangential acceleration a_t (acting in the circumferential direction of the wheel), a centrifugal acceleration a_z (acting radially outward) and a transverse acceleration a_q (acting in the transverse direction).

Essentially only centrifugal acceleration occurs at a constant driving speed on an ideally planar road surface. In reality, however, there are constant up and down movements and small lateral movements of the wheels due to minor or major irregularities in the road surface, resulting in changes in acceleration (e.g., in a tangential direction and transversely thereto). These changes in acceleration may be converted to electric power using the generator according to the present invention, i.e., used to generate electric power. The following changes in acceleration occur, for example:

1) centrifugal acceleration superimposed on twice the acceleration due to gravity plus a dynamic component in the radial direction:

$a_z = a_{z0} + a_{zg}(t) + a_{zd}(t)$,

where

a_{z0} the centrifugal acceleration which is quasistatic in this discussion,

$a_{zg}(t)=2*g*\sin(\omega*t)$, g = gravitational acceleration,
ω = angular frequency of the wheel,

$a_{zd}(t)$ the dynamic component, e.g., resulting from irregularities in the road surface.

The contribution $a_{zg}(t)=2*g*\sin(\omega*t)$ is very easily understandable due to the fact that

gravitational acceleration g (in a fixed coordinate system) always points in the same direction, but the direction of the centrifugal acceleration acting on the generator is always changing in the same fixed coordinate system.

2) Changes in tangential acceleration occur, for example, in acceleration or deceleration of the vehicle and due to irregularities in road surface:

$a_t = a_{t0} + a_{td}(t)$, where $a_{t0} \approx 0$.

3) Transverse acceleration occurs, for example, when cornering or again due to irregularities in road surface:

$a_q = a_{q0} + a_{qd}(t)$, where $a_{q0} \approx 0$.

Three embodiments of the generator are described below.

Embodiment 1:
This embodiment is shown in Figure 3. Figure 3 shows a magnetic circuit composed of

- stationary core 301,
- movable core 307 with seismic mass m,
- (small) air gap 306, which naturally changes due to the movement of core 307, and
- permanent magnet 309, which has north pole 303 and south pole 304.

Movable core 307 moves along a guide 308. The movement is limited by upper stop 305 and lower stop 311, the fastening of the stops on the housing being labeled as 312. The return of the movable core to the starting position is accomplished by restoring spring 310.

If the movable core is moved up and down (due to changes in acceleration), then the magnetic flux through coil 300 changes (due to the change in magnetic circuit

geometry and thus the change in magnetic resistance), so that a voltage U is induced in the coil. For effective operation, there should preferably be a small air gap between the poles. An upper stop and a lower stop prevent the spring from being overextended. Magnetic flux ϕ_b is induced in the coil.

Embodiment 2:

This embodiment is shown in Figure 4, where the following symbols are used (similarly to Figure 3):

400 = coil,
401 = stationary core,
402 = (small) air gap,
403 = upper stop,
404 = movable core having seismic mass m,
405 = plate spring,
406 = permanent magnet, and
407 = lower stop.

Acceleration a_0 acts on the core having mass m, which is vibratingly mounted, and thus force $F = m*a_0$ acts on the core, resulting in deflection. The vibrating part is composed of the permanent magnet and a core made of a magnetically conductive material (e.g., iron or ferrite). Due to the movement of the core, there is a time-dependent magnetic flux through the coil and thus an induced voltage $U = n*d(\phi_b)/dt$. In the position of the movable core depicted in Figure 4, magnetic flux ϕ_b flows through the coil in the direction shown. In the undeflected position (basically corresponding to the position shown in Figure 3), the magnetic flux flows in the opposite direction, i.e., the magnetic flux also undergoes a change in sign.

Embodiment 3:

This embodiment is shown in Figure 5, where

500 = coil,
501 = stationary core,
502 = movable core,

503 = permanent magnet,

504 = torsion bar.

This embodiment is almost identical to that depicted in Figure 4, essentially plate spring 405 being replaced by torsion bar 504. The seemingly complex but in principle very simple design of Figure 5 will be explained first. The left half of Figure 5 shows a top view of the stationary core and the coil from Figure 4; the right half of Figure 5 shows a top view of the movable core and the permanent magnet of Figure 4. The differences include

- the plate spring being replaced by a torsion bar and
- the outer jacket of the movable core being divided into four segments.

If the coil axis of the sensor is aligned in the radial direction, for example, then the changes in both the tangential acceleration and the transverse acceleration may be utilized to generate power. The segmented structure of outer jacket 502 is not necessary, but it allows greater differences in flux to be generated and thus higher induced voltages. This embodiment must also have a stop for limiting the deflecting movement.

Figure 1 shows how the power supply is embedded in the overall system, block 101 indicating the generator described above, its output voltage U, which is induced as a function of time, being sent to rectifier 102. Block 102 also includes a current limiter which might be necessary. This is followed by an energy storage device 103 (e.g., a battery or a capacitor) which is charged by the direct current supplied by block 102. Energy storage device 103 is followed by a voltage limiter 104, which is connected to pressure sensor 105. Block 105 also includes the analyzer circuit, the coder and the transmitter.